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Mapping Mentoring Networks: An SNA Approach to Quality, Growth, and Equity

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Mentoring plays a vital role in professional and academic development, yet traditional evaluation methods often fail to capture the complex structural dynamics and equity considerations within mentoring networks. This study introduces a multidimensional Social Network Analysis (SNA) framework designed to assess mentoring structure, relationship quality, network growth, and equitable access. Using synthetic data representing 100 participants across three program phases, the mentoring network was modeled with weighted, directed edges based on interaction frequency and perceived usefulness. Centrality and clustering metrics were calculated to capture key structural features and evolving network connectivity. Equity analyses disaggregated results by gender, race, and first-generation status to identify disparities in access to influential mentoring positions. Findings indicate that network connectivity and integration increased over time, with participants holding higher centrality, particularly mentors, occupying pivotal roles. These individuals, referred to as mentoring leaders, maintained consistent prominence throughout the program. However, female and non-binary participants were, on average, less centrally positioned, revealing structural imbalances in mentoring access. The study also examined the relationship between network position and participant outcomes. Higher centrality was associated with greater retention, suggesting that robust mentoring ties support continued engagement. In contrast, satisfaction showed weak correlations with structural metrics, underscoring the importance of mentoring quality alongside network access. By combining structural and qualitative dimensions of mentoring, this SNA-based framework provides actionable insights for program designers and researchers. Visualizing mentoring network growth and equity gaps enables the development of more effective, inclusive, and data-informed mentoring programs. While synthetic data limits generalizability, the approach offers a replicable model for future empirical studies aimed at fostering equitable mentoring in academic and professional settings.

Keywords: Equity in mentoring, mentoring programs, network centrality, retention and satisfaction, Social Network Analysis (SNA),

Introduction

Mentoring plays a pivotal role in supporting individuals' academic, professional, and personal development. It is widely recognized across disciplines and institutions as a key strategy for enhancing learning, building confidence, and promoting long-term career success (Eby et al., 2008; Allen et al., 2008). Structured mentoring programs have been associated with numerous positive outcomes, including increased retention, higher satisfaction, and stronger academic and professional performance (Kezar et al., 2018).

However, traditional methods of evaluating mentoring tend to focus on self-reported satisfaction or outcomes at the individual level. These approaches, while useful, often fail to capture the complex web of relationships that define mentoring in real-world settings (Higgins & Kram, 2001).

Mentoring does not occur in isolation. Instead, it unfolds within larger networks of relationships, shaped by institutional structures, individual identities, and patterns of inclusion and exclusion. Some participants may find themselves at the center of these networks, benefiting from multiple connections and high-quality interactions, while others may be peripheral or disconnected. Without tools to visualize and analyze these patterns, program administrators and researchers may miss important dynamics that influence program effectiveness and equity (Petrescu-Prahova et al., 2015).

This study applies Social Network Analysis (SNA) to map mentoring relationships, examining who is connected, the strength of those ties, and how the network evolves. By incorporating interaction frequency and usefulness, it captures mentoring quality beyond simple connection counts. The analysis also explores how gender,

race, and first-generation status relate to network position, using an equity lens to assess access. Finally, it links network characteristics to satisfaction and retention, revealing how structure influences outcomes (Borgatti & Halgin, 2011).

By leveraging SNA and a multidimensional dataset, this research contributes to the growing field of mentoring evaluation and responds to calls for more nuanced, data-driven, and equity-centered approaches. The findings aim to inform the design and implementation of mentoring programs that are not only effective but also inclusive and equitable. To guide this inquiry, the study asks: (1) What patterns and structures characterize mentoring networks in a professional development context? (2) How do participant attributes such as gender, race, and first-generation status relate to network position and mentoring quality? (3) In what ways do network characteristics influence satisfaction and retention outcomes?

Literature Review

The evaluation of mentoring has evolved from relying primarily on simple satisfaction surveys to employing more robust, data-informed methodologies. Eby et al. (2008) and Allen et al. (2008) have consistently demonstrated that mentoring positively impacts personal development, academic achievement, and career advancement, particularly for underrepresented populations. However, traditional studies often rely on individual-level metrics and dyadic models, focusing on single mentor-mentee pairs, without capturing the larger relational environment in which mentoring occurs.

Theoretical frameworks have expanded our understanding of mentoring by introducing the concept of developmental networks, constellations of individuals who provide various forms of support, including emotional, academic, and career guidance (Higgins & Kram, 2001). This network-based approach has gained increasing traction, with recent studies emphasizing the role of mentoring ecosystems and institutional structures in shaping access and outcomes (Kezar et al., 2018; Dawson et al., 2015). Moreover, scholars have called for more inclusive and equity-minded models that examine how social identities and institutional contexts affect individuals' positions within mentoring networks (Blake-Beard et al., 2020). This shift from isolated pairs to interconnected networks reflects the complex social ecology in which mentoring operates. It also raises critical questions about access, equity, and distribution of mentoring resources across different participant groups.

SNA is a methodological approach used to examine relationships among individuals, groups, or entities by mapping and analyzing the structure of connections within a network. It has been recognized as a valuable tool to address questions of equity and effectiveness in mentoring. SNA allows for the visualization and measurement of relationships within a network, offering insights into patterns of inclusion, exclusion, and influence. For instance, Petrescu-Prahova et al. (2015) used SNA to map mentoring and collaboration patterns in a public health program, identifying disparities in access to key individuals. Similarly, Borgatti and Halgin (2011) argue that network position, such as centrality or betweenness, can influence an individual's access to resources, information, and social capital.

Despite the promise of SNA, there remains a gap in the literature connecting network structure to meaningful outcomes such as satisfaction, retention, or perceived quality of mentorship. Moreover, few studies incorporate measures of mentoring quality, such as usefulness or interaction frequency, alongside structural metrics. Even fewer apply an equity lens to evaluate whether marginalized groups experience different patterns of connection or benefit.

This study addresses these gaps by proposing a multidimensional Social Network Analysis (SNA) framework that incorporates both network structure (e.g., centrality, density) and mentoring quality (e.g., interaction frequency and perceived usefulness), while disaggregating results by race, gender, and first-generation status. This approach directly responds to Kezar et al. (2018), who emphasize the need for equity-minded evaluation methods that move beyond individual outcomes to consider institutional and structural influences. By integrating concepts from developmental network theory (Higgins & Kram, 2001) and equity-focused scholarship, the study operationalizes mentoring as a dynamic, networked process influenced by social location and access to support. In doing so, it contributes to a growing body of literature at the intersection of social capital, network theory, and professional development.

Methodology

This study used a simulation-based approach to model and analyze mentoring networks within a professional development context. Synthetic data were generated for 100 participants using Python and the NetworkX library, with attributes including gender, race, first-generation status, role (mentor or mentee), satisfaction score (1–5), and retention status (Y/N). The mentoring network was constructed by simulating directed ties based on plausible patterns of interaction frequency and perceived usefulness, informed by findings from prior studies of mentoring programs in higher education. Synthetic data were used to allow full control over network structure and attribute distributions while protecting privacy and enabling reproducibility. Although synthetic data limits the generalizability of findings to real-world populations, they provide a valuable testbed for exploring methods, identifying equity-relevant patterns, and generating hypotheses for future empirical validation. The dataset was designed to reflect realistic demographic variation and mentoring outcomes observed in academic and

professional settings.

Mentoring relationships were simulated across three timepoints, T1, T2, and T3, to capture network growth and evolution over time. At each timepoint, 120 mentor-mentee interactions were created, each with an associated frequency (1–5) and usefulness score (1–5). These variables were used to weigh the edges in the network, with edge weight = frequency × usefulness. The interaction data were stored in a relationship table, while participant information was maintained in a separate attribute table.

Table 1:
Sample of Participant Attributes

Person ID	Role	Gender	Race	First Gen	Satisfaction Score	Retained
P001	Mentee	Female	Black	Yes	4	Y
P002	Mentor	Male	Asian	No	5	Y
...	...	...	...	...	...	...

Table 2:
Sample of Mentoring Relationships

Mentor ID	Mentee ID	Frequency	Usefulness Score	Timepoint	Edge Weight
P002	P045	4	5	T1	20
P005	P031	3	2	T2	6

The analysis was conducted using Python, primarily with the NetworkX and pandas libraries. Directed graphs were built for each timepoint using mentor-to-mentee relationships as edges. Centrality metrics, including degree, betweenness, and closeness, were calculated for each participant. These metrics served as proxies for visibility, connectivity, and access within the network.

To assess structural change, three network visualizations were generated using a spring layout. Node size was mapped to degree centrality to highlight prominent individuals within the network. Comparative bar plots illustrated average centrality values by gender across timepoints, while boxplots compared degree centrality distributions by retention status.

Equity analysis was conducted by disaggregating network metrics by gender, race, and first-generation status. Summary tables and visualizations revealed subtle disparities in access to central network positions, especially for participants from underrepresented groups. For example, female and non-binary participants showed slightly lower average degree centrality, while first-generation participants were more frequently located on the network periphery.

To explore the relationship between network position and program outcomes, correlation analyses were conducted between centrality metrics and satisfaction scores. While results showed generally weak correlations, closeness centrality displayed a modest negative correlation with satisfaction, suggesting that proximity alone does not guarantee a positive mentoring experience. These findings underscore the importance of considering both quality and structure in network-based mentoring evaluation.

Overall, the methodology offers a replicable framework for capturing and analyzing mentoring network dynamics in a way that supports continuous improvement and equity-focused program design.

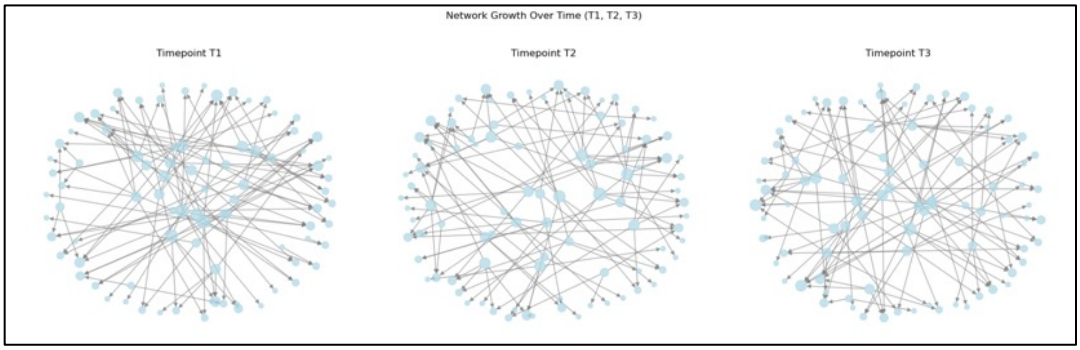
Results

The results of the network analysis illuminate key dynamics in mentoring structure, participant engagement, and equity patterns across the three timepoints (T1, T2, T3). The simulated dataset and SNA framework enabled a detailed assessment of how network connectivity evolved, who occupied central positions, and how these structural features correlated with participant outcomes.

As shown in Figure 1, the mentoring network demonstrates a clear progression in density and integration over time. The network at T1 is relatively sparse, with multiple disconnected nodes and clusters. By T3, the network exhibits a more cohesive structure, characterized by increase in connectivity and a reduction in peripheral nodes.

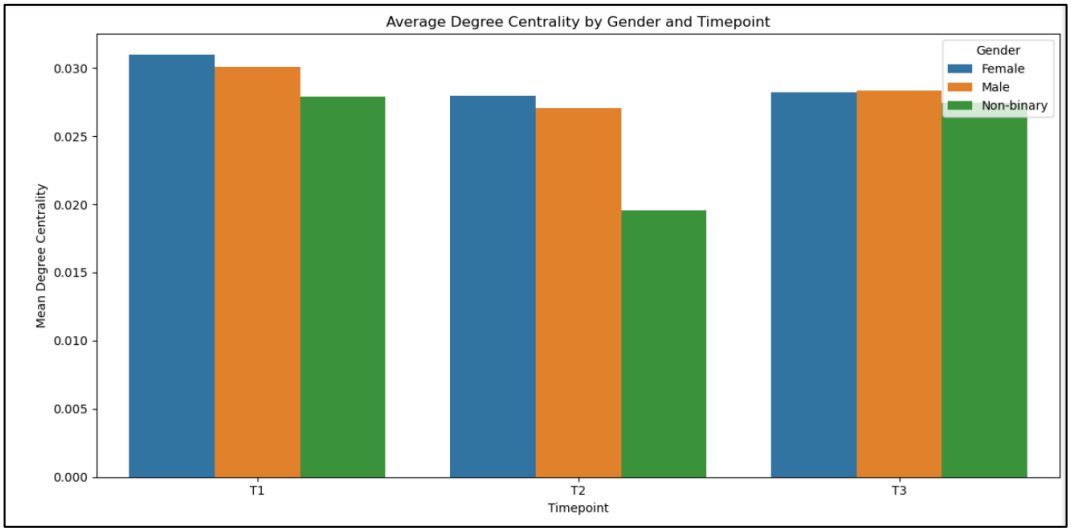
This pattern suggests a positive trajectory in mentoring engagement and a broader diffusion of relationships across the cohort. Centrality metrics provided insight into individual participants' structural positions. The visualizations present the network with node sizes scaled by degree centrality. Individuals with high centrality, predominantly mentors, occupied pivotal positions in the network, facilitating multiple connections. These central actors maintained their prominence across time points, indicating the presence of stable mentoring leaders within the system.

Figure 1:
Network Growth Over Time (T1, T2, T3): Visualization of evolving mentoring structure



As shown in Figure 2, equity analyses examine the distribution of degree centrality by gender. Across all three timepoints, male participants exhibit marginally higher average centrality scores compared to their female and non-binary counterparts. While the differences are modest, their persistence across time points raises important considerations regarding equitable access to influential mentoring relationships.

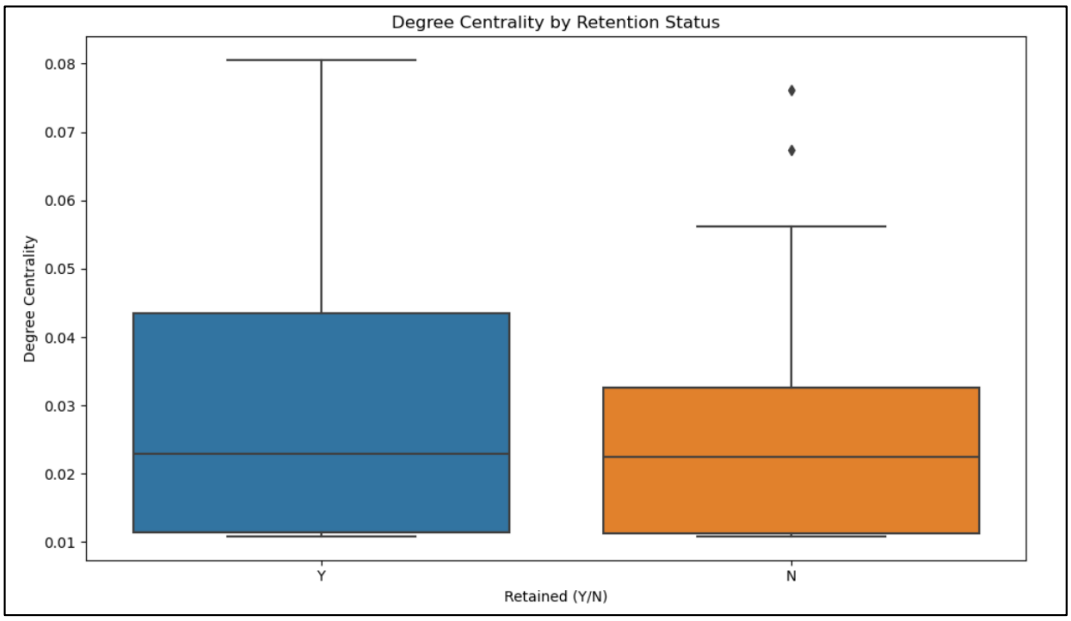
Figure 2:
Bar Plot: Average Degree Centrality by Gender and Timepoint



The association between network engagement and program persistence is further explored in Figure 3, which compares degree centrality by retention status. Retained participants display higher median centrality values, suggesting that more robust mentoring connections may be associated with continued participation.

Nonetheless, the overlapping distributions indicate that network centrality is likely one of multiple factors influencing retention decisions.

Figure 3:
Boxplot: Degree Centrality by Retention Status (Y/N)



Correlation analyses between centrality metrics and satisfaction scores revealed limited associations. Degree and betweenness centrality were not significantly correlated with satisfaction, while closeness centrality exhibited a weak negative correlation. These findings suggest that occupying a structurally central position in the network does not necessarily equate to a more satisfying mentoring experience, underscoring the importance of mentoring quality in addition to structural access.

Taken together, the results highlight the utility of Social Network Analysis in capturing the dynamic and relational aspects of mentoring programs. The findings point to evolving engagement patterns, the persistence of individuals in central structural positions, referred to here as mentoring leaders, and nuanced equity gaps that merit further attention.

These mentoring leaders were operationalized as participants with consistently high degree centrality across timepoints, indicating their role in maintaining multiple and potentially influential connections within the network. Moreover, the observed link between network centrality and participant retention supports the value of intentional relationship-building strategies in mentoring program design and implementation.

Discussion

This study contributes to mentoring research by introducing a multidimensional Social Network Analysis (SNA) framework to evaluate structure, quality, and equity. Key quantitative findings revealed that network density and integration increased across timepoints (T1–T3), centrality was positively associated with retention status,
and gender-based disparities in network centrality persisted over time. Notably, satisfaction scores showed limited correlation with centrality measures, emphasizing the distinction between structural engagement and perceived mentoring quality.

These results highlight mentoring as a dynamic network shaped by institutional roles and participant identities. The observed growth in connectivity and integration by T3 suggests that scaling opportunities for interaction can enhance inclusivity and engagement, aligning with prior research on the developmental benefits of network expansion (Higgins & Kram, 2001; Petrescu-Prahova et al., 2015).

However, the persistent disparities in centrality metrics by gender raise concerns about structural inequities within the network. Despite overall improvements in connectivity, female and non-binary participants remained less central on average, indicating that inclusion does not necessarily translate into equal access to influential mentoring positions. This observation supports calls from scholars such as Kezar et al. (2018) for mentoring designs that explicitly address equity and inclusion. The weak link between centrality and satisfaction underscores that access alone does not ensure meaningful mentoring. In contrast, the positive association with retention highlights the value of frequent, high-quality connections in supporting persistence.

Despite offering valuable insights, this study has limitations. The use of synthetic data, while methodologically consistent, may not capture

the full complexity of real-world mentoring contexts. Additionally, the absence of longitudinal satisfaction data constrains the analysis of how perceptions evolve over time. These limitations highlight the need for future research to apply this framework to empirical datasets and incorporate longitudinal measures to assess the sustained impact of network interventions. Nonetheless, the findings underscore the potential of SNA to reveal underlying mentoring dynamics and support the development of equity-focused, data-informed program designs adaptable across academic, professional, and community settings.

Conclusion

This study demonstrates how a SNA approach can enrich our understanding of mentoring programs by revealing structural patterns, highlighting equity gaps, and linking network characteristics to participant outcomes. By simulating a dynamic mentoring environment, the study identified how network growth, centrality, and interaction quality influence key outcomes such as satisfaction and retention. The findings suggest that highly connected individuals, particularly those who engage in frequent and useful mentoring interactions, are more likely to remain in the program and serve as influential actors within the network. However, the consistent disparities in centrality among gender groups underscore the need for intentional design strategies that promote inclusive access to mentoring resources. Furthermore, the weak correlation between network position and satisfaction points to the importance of fostering not only access but also meaningful and high-quality mentoring relationships.

For practitioners, the results provide actionable insights for improving mentoring program design. Specifically, programs should prioritize relationship-building structures that promote broad engagement while monitoring equity in access to central mentoring roles. Evaluating both the structure and perceived value of interactions allows for a more comprehensive and equitable assessment of program effectiveness.

While this study employed synthetic data to demonstrate methodological utility, future research should apply the framework to real-world contexts with longitudinal tracking to validate and extend its findings. When integrated with equity considerations and outcome measures, SNA offers a robust and scalable approach for designing mentoring programs that are both effective and inclusive. By providing actionable insights into mentoring dynamics and structural inequities, this framework empowers practitioners and researchers to build data-informed, equity-driven programs that foster meaningful connections and advance lasting success for all participants.

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